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INHYD: Computer Code for Intraply Hybrid Composite Design

Users Manual

Christos C. Chamis
and John H. Sinclair

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INHYD: Computer Code for Intraply Hybrid Composite Design

Users Manual

Christos C. Chamis
and John H. Sinclair

Lewis Research Center
Cleveland, Ohio

NASA

National Aeronautics
and Space Administration

**Scientific and Technical
Information Branch**

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Summary

A computer program called INHYD has been developed for intraply hybrid composite design. This report is a users manual for INHYD. INHYD embodies several composite micromechanics theories, intraply hybrid composite theories, and an integrated hygrothermomechanical theory. INHYD can be run in both interactive and batch modes. It has considerable flexibility and capability, which the user can exercise through several options. These options are demonstrated through appropriate INHYD runs in the manual.

Introduction

Intraply hybrid composites have been investigated theoretically and experimentally at Lewis over the past several years. Theories developed during these investigations and corroborated by attendant experiments were used to develop a computer program identified as INHYD (INtraply HYbrid composite Design). INHYD was designed to operate in the interactive and batch modes. This report is a users manual for INHYD.

INHYD includes several composite micromechanics theories, intraply hybrid composite theories, and an integrated hygrothermomechanical theory. Equations from these theories are used by the program as appropriate for the user's specific applications. The elements and subroutines in INHYD are summarized in appendix A. The capabilities of the INHYD computer code are described in appendix B. The symbols used in the program are defined in appendix C. Before running INHYD for the first time, the user should read the program capability description in appendix B, which is a reproduction of NASA TM-82593 included herein for completeness.

First, the manual presents examples for the interactive mode—for a dry, room-temperature case and then for a case with moisture present. Then an interactive case is described, where the data are preentered as they would be for a batch case. Next batch cases are described. After following through the test cases given, a user should be able to use INHYD either in the interactive or batch mode and with or without temperature and moisture effects to predict properties for uniaxial intraply hybrid composites.

INHYD Interactive Mode

Ambient Conditions, Dry

To run INHYD, the user must first install and compile the program on his/her computer according to the system in use. The procedure used on the Lewis Research Center's UNIVAC 1100 is described in detail here by using the actual computer printout. Computer prompt signals are identified with upper-case letters. User entries follow the computer symbol >. Appropriate explanatory notes follow each printout.

```
>@asg,a inhyd.

READY
>@map,i .abs

MAP 30R1(C1) S74T11 04/22/83 11:12:46 (->0)
>in inhyd.

>end

START=012516, PROG SIZE(I/D)=10822/4956
SYS$*RLIB$. LEVEL
END MAP.  ERRORS: 0
>@xqt .abs

 INHYD TO BE RUN BATCH OR INTERACTIVE (B/I)
>i
```

As illustrated, the user is prompted by the computer, and his/her responses or entries are the input required for the run.

```
          INHYD INTERACTIVE DATA ENTRY

 SECONDARY COMPOSITE VOLUME RATIO
>.2
```

The user selected 0.2 for the secondary composite volume ratio.

```
 WHICH COMPOSITE DATA TO BE ENTERED (P/S)
>p
```

The choice was primary (P) or secondary (S); the user selected primary.

```
 PROPERTIES TO BE ENTERED (C/F/M/T)
>f
```

The choice was composite (C), fiber (F), dry matrix (M), or matrix with moisture and temperature effects (T); the user selected fiber properties for the primary composite.

```
 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>as graphite
```

This heading identifies the primary fiber property table to be printed out by the computer.

```
 ENTER THE FIBER PROPERTY VALUES
 EFP1     EFP2     GFP12    GFP23    NUFP12   NUFP23
>.32e8,.2e7,.2e7,.1e7,.2,.25

 CTEFP1   CTEFP2   RHOFP    NFP      DIFP     CFPC
>-.56e-6,.56e-5,.63e-1,.1e5,.3e-3,.17

 KFP1     KFP2     KFP3     SFPT     SFPC
>.58e3,.58e2,.58e2,.4e6,.4e6
```

Here the user has entered the 17 values for the primary fiber properties that will be used in the micromechanics for calculating the primary composite properties. (Entry headings are defined in appendix C.)

```
 PROPERTIES TO BE ENTERED (C/F/M/T)
>m
```

Dry matrix (M) was selected.

```
 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>3501-5,dry,70 degrees f
```

This heading identifies the primary matrix property table to be printed out by the computer.

```
 ENTER THE MATRIX PROPERTY VALUES
 EMP      GMP      NUMP     CTEMP    RHOMP    CMPC
>.46e6,.1643e6,.4,.32e-4,.443e-1,.25

 KMP      SMPT     SMPC     SMPS     BTAMP    DIFMP
>.125e1,.68e4,.363e5,.7e4,.4,.2e-3
```

Here the user has entered the 12 values for the primary matrix properties that will be used in the micromechanics for calculating the primary composite properties. (Entry headings are defined in appendix C.)

```
 COMPOSITE HEADING (1 TO 80 CHARACTERS)
>as/e
```

This heading identifies the primary composite property table. Table entries are to be calculated from the primary fiber properties and primary matrix properties and tabulated under this heading. The primary composite is AS/E (graphite/epoxy).

```
 ENTER  CONSTITUENT  VOLUME  RATIOS
 FIBER   MATRIX  VOID
>.55,.44,.01
```

The fiber volume ratio, matrix volume ratio, and void volume ratio of the primary composite are entered as desired by the user. The sum of the three values must be 1.0.

```
 VOID CONDUCTIVITY
>.1
```

The thermal conductivity of the voids was chosen as 0.1.

```
 METHOD FOR CALCULATING COMPOSITE PROPERTIES (H/M)
>m
```

The user can choose hygrothermomechanical theory (H) or micromechanics theory (M) for calculating the primary composite properties. Micromechanics theory was selected since moisture and temperature effects are not being studied.

```
 WHICH COMPOSITE DATA TO BE ENTERED (P/S)
>s
```

Now the secondary composite (S) properties will be calculated from the fiber and matrix properties about to be entered below. Since the procedure is the same as that used for the primary composite, fewer comments will be required.

```
 PROPERTIES TO BE ENTERED (C/F/M/T)
>f

 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>s-glass
```

The secondary fiber is S-Glass.

```
 ENTER THE FIBER PROPERTY VALUES
 EFS1     EFS2     GFS12    GFS23    NUFS12   NUFS23
>.124e8,.124e8,.517e7,.517e7,.2,.2

 CTEFS1   CTEFS2   RHOFS    NFS      DIFS     CFSC
>.28e-5,.28e-5,.9e-1,.204e3,.36e-3,.17

 KFS1     KFS2     KFS3     SFST     SFSC
>.75e1,.75e1,.75e1,.36e6,.3e6


 PROPERTIES TO BE ENTERED (C/F/M/T)
>m


 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>3501-5,dry,70 degrees f


 ENTER THE MATRIX PROPERTY VALUES
 EMS      GMS      NUMS     CTEMS    RHOMS    CMSC
>.46e6,.1643e6,.4,.32e-4,.443e-1,.25

 KMS      SMST     SMSC     SMSS     BTAMS    DIFMS
>.125e1,.68e4,.363e5,.7e4,.4,.2e-3
```

The same matrix is used for the secondary composite as was used for the primary one. If desired, a different matrix could be used.

```
 COMPOSITE HEADING (1 TO 80 CHARACTERS)
>s-glass/e


 ENTER  CONSTITUENT  VOLUME RATIOS
 FIBER    MATRIX   VOID
>.55,.44,.01


 VOID CONDUCTIVITY
>.1


 METHOD FOR CALCULATING COMPOSITE PROPERTIES (H/M)
>m


 HYBRID HEADING (1 TO 80 CHARACTERS)
>as/e//s-glass/e,80/20
```

This is the heading for the hybrid composite table that will be calculated.

```
 METHOD FOR CALCULATING HYBRID PROPERTIES (R/M)
>r
```

The choice is micromechanics theory (M) or rule of mixtures (R); the user selected the rule of mixtures.

The computer then lists the headings and properties previously entered by the user for the fibers (17 properties) and matrix (12 properties) of the primary composite in tabular form. Next it lists the respective volume ratios and the 37 calculated properties for the primary composite and a table of flexural strengths for the primary composite as calculated by several theories.

PRIMARY FIBER PROPERTIES; AS GRAPHITE

1	ELASTIC MODULI	EFP1	.3200+08
2		EFP2	.2000+07
3	SHEAR MODULI	GFP12	.2000+07
4		GFP23	.1000+07
5	POISSON'S RATIO	NUFP12	.2000+00
6		NUFP23	.2500+00
7	THERM. EXP. COEF.	CTEFP1	-.5600-06
8		CTEFP2	.5600-05
9	DENSITY	RHOFP	.6300-01
10	NO. OF FIBERS/END	NFP	.1000+05
11	FIBER DIAMETER	DIFP	.3000-03
12	HEAT CAPACITY	CFPC	.1700+00
13	HEAT CONDUCTIVITY	KFP1	.5800+03
14		KFP2	.5800+02
15		KFP3	.5800+02
16	STRENGTHS	SFPT	.4000+06
17		SFPC	.4000+06

PRIMARY MATRIX PROPERTIES; 3501-5,DRY,70 DEGREES F

1	ELASTIC MODULUS	EMP	.4600+06
2	SHEAR MODULUS	GMP	.1643+06
3	POISSON'S RATIO	NUMP	.4000+00
4	THERM. EXP. COEF.	CTEMP	.3200-04
5	DENSITY	RHOMP	.4430-01
6	HEAT CAPACITY	CMPC	.2500+00
7	HEAT CONDUCTIVITY	KMP	.1250+01
8	STRENGTHS	SMPT	.6800+04
9		SMPC	.3630+05
10		SMPS	.7000+04
11	MOISTURE COEF	BTAMP	.4000+00
12	DIFFUSIVITY	DIFMP	.2000-03

PRIMARY COMPOSITE PROPERTIES; AS/E

BASED ON MICROMECHANICS OF INTRAPLY HYBRID COMPOSITES:
ELASTIC AND THERMAL PROPERTIES.

```
FIBER VOLUME RATIO -   .550      MATRIX VOLUME RATIO -   .440
VOID CONDUCTIVITY -   .1000+00   VOID VOLUME RATIO -   .010
```

1	ELASTIC MODULI	EPC1	.1784+08
2		EPC2	.1187+07
3		EPC3	.1187+07
4	SHEAR MODULI	GPC12	.7087+06
5		GPC23	.5612+06
6		GPC13	.7087+06
7	POISSON'S RATIO	NUPC12	.2900+00
8		NUPC23	.3175+00
9		NUPC13	.2900+00
10	THERM. EXP. COEF.	CTEPC1	-.1280-06
11		CTEPC2	.1563-04
12		CTEPC3	.1563-04
13	DENSITY	RHOPC	.5414-01
14	HEAT CAPACITY	CPC	.1988+00
15	HEAT CONDUCTIVITY	KPC1	.3195+03
16		KPC2	.3702+01
17		KPC3	.3702+01
18	STRENGTHS	SPC1T	.2230+06
19		SPC1C	.2230+06
20		SPC2T	.4944+04
21		SPC2C	.2639+05
22		SPC12	.5335+04
23	MOIST. DIFFUSIVITY	DPC1	.8800-04
24		DPC2	.5168-04
25		DPC3	.5168-04
26	MOIST. EXP. COEF.	BTAPC1	.5402-02
27		BTAPC2	.1441+00
28		BTAPC3	.1441+00
29	FLEXURAL MODULI	EPC1F	.1784+08
30		EPC2F	.1187+07
31	STRENGTHS	SPC23	.5868+04
32		SPC1F	.2788+06
33		SPC2F	.1041+05
34		SPCSB	.8002+04
35	PLY THICKNESS	TPC	.5000-02
36	INTERPLY THICKNESS	PLPC	.5850-04
37	INTERFIBER SPACING	PLPCS	.5850-04

```
I*************************************************************I
I                    FLEXURAL STRENGTH                        I
I                    *****************                        I
I*************************************************************I
I THEORY              I    LONGITUDINAL    I    TRANSVERSE    I
I*************************************************************I
I BILINEAR            I      .2230+06      I      .8328+04    I
I SOLUTION            I                    I                  I
I*************************************************************I
I LINEAR RECTANGULAR  I      .2230+06      I      .9737+04    I
I SOLUTION            I                    I                  I
I*************************************************************I
I NEUTRAL AXIS SHIFT  I      .2230+06      I      .9737+04    I
I SOLUTION            I                    I                  I
I*************************************************************I
I PARABOLIC           I      .2788+06      I      .1041+05    I
I SOLUTION            I                    I                  I
I*************************************************************I
I RECTANGULAR         I      .3345+06      I      .1249+05    I
I SOLUTION            I                    I                  I
I*************************************************************I
```

The longitudinal and transverse flexural strengths listed in the composite property table (items 32 and 33) are calculated by the parabolic theory. The ply thickness (item 35) is internally set at 0.005 in., which is a typical value for most fiber composites. The ply thickness is used to calculate flexural strength.

The computer repeats this procedure for the secondary composite—first listing the data entered by the user and then tabulating the 37 calculated properties for the secondary composite (which in this example is S-Glass/epoxy) and the flexural strengths.

SECONDARY FIBER PROPERTIES; S-GLASS

1	ELASTIC MODULI	EFS1	.1240+08
2		EFS2	.1240+08
3	SHEAR MODULI	GFS12	.5170+07
4		GFS23	.5170+07
5	POISSON'S RATIO	NUFS12	.2000+00
6		NUFS23	.2000+00
7	THERM. EXP. COEF.	CTEFS1	.2800-05
8		CTEFS2	.2800-05
9	DENSITY	RHOFS	.9000-01
10	NO. OF FIBERS/END	NFS	.2040+03
11	FIBER DIAMETER	DIFS	.3600-03
12	HEAT CAPACITY	CFSC	.1700+00
13	HEAT CONDUCTIVITY	KFS1	.7500+01
14		KFS2	.7500+01
15		KFS3	.7500+01
16	STRENGTHS	SFST	.3600+06
17		SFSC	.3000+06

SECONDARY MATRIX PROPERTIES; 3501-5,DRY,70 DEGREES F

1	ELASTIC MODULUS	EMS	.4600+06
2	SHEAR MODULUS	GMS	.1643+06
3	POISSON'S RATIO	NUMS	.4000+00
4	THERM. EXP. COEF.	CTEMS	.3200-04
5	DENSITY	RHOMS	.4430-01
6	HEAT CAPACITY	CMSC	.2500+00
7	HEAT CONDUCTIVITY	KMS	.1250+01
8	STRENGTHS	SMST	.6800+04
9		SMSC	.3630+05
10		SMSS	.7000+04
11	MOISTURE COEF	BTAMS	.4000+00
12	DIFFUSIVITY	DIFMS	.2000-03

SECONDARY COMPOSITE PROPERTIES; S-GLASS/E

BASED ON MICROMECHANICS OF INTRAPLY HYBRID COMPOSITES:
ELASTIC AND THERMAL PROPERTIES.

FIBER VOLUME RATIO - .550 MATRIX VOLUME RATIO - .440
VOID CONDUCTIVITY - .1000+00 VOID VOLUME RATIO - .010

1	ELASTIC MODULI	ESC1	.7061+07
2		ESC2	.1881+07
3		ESC3	.1881+07
4	SHEAR MODULI	GSC12	.8449+06
5		GSC23	.8449+06
6		GSC13	.8449+06
7	POISSON'S RATIO	NUSC12	.2900+00
8		NUSC23	.2900+00
9		NUSC13	.2900+00
10	THERM. EXP. COEF.	CTESC1	.3779-05
11		CTESC2	.1348-04
12		CTESC3	.1348-04
13	DENSITY	RHOSC	.6899-01
14	HEAT CAPACITY	CSC	.1926+00
15	HEAT CONDUCTIVITY	KSC1	.4675+01
16		KSC2	.2750+01
17		KSC3	.2750+01
18	STRENGTHS	SSC1T	.2050+06
19		SSC1C	.1708+06
20		SSC2T	.4223+04
21		SSC2C	.2254+05
22		SSC12	.4842+04
23	MOIST. DIFFUSIVITY	DSC1	.8800-04
24		DSC2	.5168-04
25		DSC3	.5168-04
26	MOIST. EXP. COEF.	BTASC1	.1365-01
27		BTASC2	.1433+00
28		BTASC3	.1433+00
29	FLEXURAL MODULI	ESC1F	.7061+07
30		ESC2F	.1881+07

31	STRENGTHS	SSC23	.4842+04
32		SSC1F	.2329+06
33		SSC2F	.8892+04
34		SSCSB	.7263+04
35	PLY THICKNESS	TSC	.5000-02
36	INTERPLY THICKNESS	PLSC	.7020-04
37	INTERFIBER SPACING	PLSCS	.7020-04

FLEXURAL STRENGTH

THEORY	LONGITUDINAL	TRANSVERSE
BILINEAR SOLUTION	.1864+06	.7114+04
LINEAR RECTANGULAR SOLUTION	.2019+06	.8317+04
NEUTRAL AXIS SHIFT SOLUTION	.2019+06	.8317+04
PARABOLIC SOLUTION	.2329+06	.8892+04
RECTANGULAR SOLUTION	.2795+06	.1067+05

Finally the calculated hybrid composite property (35 properties) and hybrid composite flexural strength tables are printed out.

HYBRID COMPOSITE PROPERTIES; AS/E//A S-GLASS/E,80/20

BASED ON PREDICTION OF PROPERTIES OF INTRAPLY HYBRID COMPOSITES (RULE OF MIXTURES).

PRIMARY COMPOSITE VOLUME RATIO - .800

SECONDARY COMPOSITE VOLUME RATIO - .200

1	ELASTIC MODULI	EHC1	.1568+08
2		EHC2	.1326+07
3		EHC3	.1326+07
4	SHEAR MODULI	GHC12	.7360+06
5		GHC23	.6180+06
6		GHC13	.7360+06
7	POISSON'S RATIO	NUHC12	.2900+00
8		NUHC23	.3120+00
9		NUHC13	.2900+00
10	THERM. EXP. COEF.	CTEHC1	.6534-06
11		CTEHC2	.1520-04
12		CTEHC3	.1520-04
13	DENSITY	RHOHC	.5711-01
14	HEAT CAPACITY	CHC	.1976+00
15	HEAT CONDUCTIVITY	KHC1	.2566+03
16		KHC2	.3511+01
17		KHC3	.3511+01
18	STRENGTHS	SHC1T	.2194+06
19		SHC1C	.2126+06
20		SHC2T	.4800+04
21		SHC2C	.2562+05
22		SHC12	.5236+04
23	MOIST. DIFFUSIVITY	DHC1	.8800-04
24		DHC2	.5168-04
25		DHC3	.5168-04
26	MOIST. EXP. COEF.	BTAHC1	.7052-02
27		BTAHC2	.1440+00
28		BTAHC3	.1440+00
29	FLEXURAL MODULI	EHC1F	.1568+08

```
        30                                EHC2F        .1326+07
        31    STRENGTHS                   SHC23        .5663+04
        32                                SHC1F        .2699+06
        33                                SHC2F        .1011+05
        34                                SHCSB        .7854+04
        35    FIBER VOL. RATIO            VFH          .5500+00
```

```
I*******************************************************************I
I                       FLEXURAL STRENGTH                           I
I                       *****************                           I
I*******************************************************************I
I THEORY              I    LONGITUDINAL    I    TRANSVERSE         I
I*******************************************************************I
I BILINEAR            I      .2159+06      I      .8085+04         I
I SOLUTION            I                    I                       I
I*******************************************************************I
I LINEAR RECTANGULAR  I      .2193+06      I      .9453+04         I
I SOLUTION            I                    I                       I
I*******************************************************************I
I NEUTRAL AXIS SHIFT  I      .2193+06      I      .9453+04         I
I SOLUTION            I                    I                       I
I*******************************************************************I
I PARABOLIC           I      .2699+06      I      .1011+05         I
I SOLUTION            I                    I                       I
I*******************************************************************I
I RECTANGULAR         I      .3239+06      I      .1213+05         I
I SOLUTION            I                    I                       I
I*******************************************************************I
```

With Moisture Effects

An example for the same composite, 80/20 AS/E//S-G/E, but with moisture and temperature effects is presented below. Only features differing from those explained in the previous "dry" example are explained.

```
>@asg,a inhyd.

READY
>@map,i .abs

MAP 30R1(C1) S74T11 04/22/83 11:37:55 (->0)
>in inhyd.

>end

START=012516, PROG SIZE(I/D)=10822/4956
SYS$*RLIB$. LEVEL
END MAP.  ERRORS: 0
>@xqt .abs

 INHYD TO BE RUN BATCH OR INTERACTIVE (B/I)
>i


           INHYD INTERACTIVE DATA ENTRY

 SECONDARY COMPOSITE VOLUME RATIO
>.2


 WHICH COMPOSITE DATA TO BE ENTERED (P/S)
>p


 PROPERTIES TO BE ENTERED (C/F/M/T)
>f


 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>as graphite
```

```
 ENTER THE FIBER PROPERTY VALUES
 EFP1     EFP2     GFP12    GFP23    NUFP12   NUFP23
>.32e8,.2e7,.2e7,.1e7,.2,.25

 CTEFP1   CTEFP2   RHOFP    NFP      DIFP     CFPC
>-.56e-6,.56e-5,.63e-1,.1e5,.3e-3,.17

 KFP1     KFP2     KFP3     SFPT     SFPC
>.58e3,.58e2,.58e2,.4e6,.4e6


 PROPERTIES TO BE ENTERED (C/F/M/T)
>t
```

The matrix with moisture and temperature properties (T) was selected. Now additional input is needed for the matrix. Nineteen entries are needed instead of the 12 required for the previous case:

```
 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>3501-5,with 2% moisture


 ENTER THE MATRIX PROPERTY VALUES
 EMP      GMP      NUMP     CTEMP    RHOMP    CMPC
>.46e6,.1643e6,.4,.32e-4,.443e-1,.25

 KMP      SMPT     SMPC     SMPS     BTAMP    DIFMP
>.125e1,.68e4,.363e5,.7e4,.4,.2e-3


 ENTER THE THERMAL/MOISTURE PROPERTY VALUES
 TO       TGDR     TEMP     MOIST (%)
>273.,460.,294.,2.0
```

The first three new entries in the above line are the reference temperature, the glass transition temperature of the resin, and the use temperature. Here they are entered in Kelvin, but any scale can be used since it is a ratio of differences. If Fahrenheit were used, the entries would be 32°, 368°, and 70°, respectively. The last entry is for 2 percent moisture. In addition the following three entries are needed:

```
 KMST     CMST     RHOMST
>.1,.1,1.0
```

These entries are the conductivity, the heat capacity, and the density of the moisture substance (see INHYD.INSTR).

```
 COMPOSITE HEADING (1 TO 80 CHARACTERS)
>as/e with 2% moisture in matrix


 ENTER CONSTITUENT VOLUME RATIOS
 FIBER    MATRIX   VOID
>.55,.44,.01


 VOID CONDUCTIVITY
>.1


 METHOD FOR CALCULATING COMPOSITE PROPERTIES (H/M)
>h
```

Hygrothermomechanical theory was selected since 2 percent moisture is present in the matrix.

```
 WHICH COMPOSITE DATA TO BE ENTERED (P/S)
>s


 PROPERTIES TO BE ENTERED (C/F/M/T)
>f
```

```
 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>s-glass


 ENTER THE FIBER PROPERTY VALUES
 EFS1     EFS2     GFS12    GFS23    NUFS12   NUFS23
>.124e8,.124e8,.517e7,.517e7,.2,.2

 CTEFS1   CTEFS2   RHOFS    NFS      DIFS     CFSC
>.28e-5,.28e-5,.9e-1,.204e3,.36e-3,.17

 KFS1     KFS2     KFS3     SFST     SFSC
>.75e1,.75e1,.75e1,.36e6,.3e6


 PROPERTIES TO BE ENTERED (C/F/M/T)
>t


 INPUT DATA HEADING (1 TO 80 CHARACTERS)
>3501-5 with 2% moisture



 ENTER THE MATRIX PROPERTY VALUES
 EMS      GMS      NUMS     CTEMS    RHOMS    CMSC
>.46e6,.1643e6,.4,.32e-4,.443e-1,.25

 KMS      SMST     SMSC     SMSS     BTAMS    DIFMS
>.125e1,.68e4,.363e5,.7e4,.4,.2e-3


 ENTER THE THERMAL/MOISTURE PROPERTY VALUES
 TO       TGDR     TEMP     MOIST (%)
>273.,460.,294.,2.0

 KMST     CMST     RHOMST
>.1,.1,1.0


 COMPOSITE HEADING (1 TO 80 CHARACTERS)
>s-glass with 2% moisture in matrix


 ENTER  CONSTITUENT  VOLUME RATIOS
 FIBER    MATRIX  VOID
>.55,.44,.01


 VOID CONDUCTIVITY
>.1


 METHOD FOR CALCULATING COMPOSITE PROPERTIES (H/M)
>h


 HYBRID HEADING (1 TO 80 CHARACTERS)
>as/e//s-g/e,80/20 with 2% moisture in matrix


 METHOD FOR CALCULATING HYBRID PROPERTIES (R/M)
>r
```

The choice is rule of mixtures (R) or micromechanical theory (M); the user selected the rule of mixtures.

```
PRIMARY FIBER PROPERTIES; AS GRAPHITE
      1     ELASTIC MODULI         EFP1        .3200+08
      2                            EFP2        .2000+07
      3     SHEAR MODULI           GFP12       .2000+07
      4                            GFP23       .1000+07
      5     POISSON'S RATIO        NUFP12      .2000+00
      6                            NUFP23      .2500+00
      7     THERM. EXP. COEF.      CTEFP1     -.5600-06
```

8		CTEFP2	.5600-05
9	DENSITY	RHOFP	.6300-01
10	NO. OF FIBERS/END	NFP	.1000+05
11	FIBER DIAMETER	DIFP	.3000-03
12	HEAT CAPACITY	CFPC	.1700+00
13	HEAT CONDUCTIVITY	KFP1	.5800+03
14		KFP2	.5800+02
15		KFP3	.5800+02
16	STRENGTHS	SFPT	.4000+06
17		SFPC	.4000+06

PRIMARY MATRIX PROPERTIES; 3501-5,WITH 2% MOISTURE

REFERENCE TEMP. - 273.00
TEST TEMP. - 294.00
MOISTURE CONDUCTIVITY - .1000+00
MOISTURE DENSITY - .1000+01
DRY GLASS TRANS. TEMP. - 460.00
PCT. MOISTURE - 2.000
MOISTURE HEAT CAPACITY - .1000+00

ORIGINAL MATRIX PROPERTIES

1	ELASTIC MODULUS	EMP	.4600+06
2	SHEAR MODULUS	GMP	.1643+06
3	POISSON'S RATIO	NUMP	.4000+00
4	THERM. EXP. COEF.	CTEMP	.3200-04
5	DENSITY	RHOMP	.4430-01
6	HEAT CAPACITY	CMPC	.2500+00
7	HEAT CONDUCTIVITY	KMP	.1250+01
8	STRENGTHS	SMPT	.6800+04
9		SMPC	.3630+05
10		SMPS	.7000+04
11	MOISTURE COEF	BTAMP	.4000+00
12	DIFFUSIVITY	DIFMP	.2000-03

The user's input is tabulated in the preceding tables.

NEW PROPERTIES: CHANGED BECAUSE
OF TEMPERATURE/MOISTURE EFFECTS

*	NEW EMP	.3068+06
*	NEW GMP	.1096+06
*	NEW NUMP	.4000+00
*	NEW CTEMP	.4797-04
*	NEW RHOMP	.4547-01
*	NEW CMPC	.3748+00
*	NEW KMP	.1874+01
*	NEW SMPT	.4536+04
*	NEW SMPC	.2421+05
*	NEW SMPS	.4669+04
*	NEW BTAMP	.4000+00
*	NEW DIFMP	.2000-03

Temperature and moisture effects on the matrix are calculated and tabulated by the computer in the preceding table. These two tables are printed out side by side.

PRIMARY COMPOSITE PROPERTIES; AS/E WITH 2% MOISTURE IN MATRIX

BASED ON INTEGRATED THEORY FOR PREDICTING THE HYGROTHERMOMECHANICAL

RESPONSE OF ADVANCED COMPOSITE STRUCTURAL COMPONENTS.

FIBER VOLUME RATIO - .550 MATRIX VOLUME RATIO - .440
VOID CONDUCTIVITY - .1000+00 VOID VOLUME RATIO - .010

1	ELASTIC MODULI	EPC1	.1776+08
2		EPC2	.9275+06
3		EPC3	.9275+06
4	SHEAR MODULI	GPC12	.5181+06
5		GPC23	.4346+06

6		GPC13	.5181+06
7	POISSON'S RATIO	NUPC12	.2860+00
8		NUPC23	.6711-01
9		NUPC13	.2860+00
10	THERM. EXP. COEF.	CTEPC1	-.1208-06
11		CTEPC2	.2146-04
12		CTEPC3	.2146-04
13	DENSITY	RHOPC	.5466-01
14	HEAT CAPACITY	CPC	.2450+00
15	HEAT CONDUCTIVITY	KPC1	.3198+03
16		KPC2	.5407+01
17		KPC3	.5407+01
18	STRENGTHS	SPC1T	.2220+06
19		SPC1C	.1231+06
20		SPC2T	.4470+04
21		SPC2C	.2386+05
22		SPC12	.4601+04
23	MOIST. DIFFUSIVITY	DPC1	.8800-04
24		DPC2	.5168-04
25		DPC3	.5168-04
26	MOIST. EXP. COEF.	BTAPC1	.3620-02
27		BTAPC2	.1126+00
28		BTAPC3	.1126+00
29	FLEXURAL MODULI	EPC1F	.1776+08
30		EPC2F	.9275+06
31	STRENGTHS	SPC23	.4601+04
32		SPC1F	.1980+06
33		SPC2F	.9411+04
34		SPCSB	.6902+04
35	PLY THICKNESS	TPC	.5000-02
36	INTERPLY THICKNESS	PLPC	.5850-04
37	INTERFIBER SPACING	PLPCS	.5850-04

FLEXURAL STRENGTH

THEORY	LONGITUDINAL	TRANSVERSE
BILINEAR SOLUTION	.1584+06	.7529+04
LINEAR RECTANGULAR SOLUTION	.1937+06	.8802+04
NEUTRAL AXIS SHIFT SOLUTION	.1937+06	.8802+04
PARABOLIC SOLUTION	.1980+06	.9411+04
RECTANGULAR SOLUTION	.2376+06	.1129+05

The primary composite flexural strength table concludes the primary composite calculations. User input for the secondary composite is now tabulated.

SECONDARY FIBER PROPERTIES; S-GLASS

1	ELASTIC MODULI	EFS1	.1240+08
2		EFS2	.1240+08
3	SHEAR MODULI	GFS12	.5170+07
4		GFS23	.5170+07
5	POISSON'S RATIO	NUFS12	.2000+00
6		NUFS23	.2000+00
7	THERM. EXP. COEF.	CTEFS1	.2800-05
8		CTEFS2	.2800-05
9	DENSITY	RHOFS	.9000-01
10	NO. OF FIBERS/END	NFS	.2040+03
11	FIBER DIAMETER	DIFS	.3600-03
12	HEAT CAPACITY	CFSC	.1700+00
13	HEAT CONDUCTIVITY	KFS1	.7500+01
14		KFS2	.7500+01
15		KFS3	.7500+01

16	STRENGTHS	SFST	.3600+06
17		SFSC	.3000+06

SECONDARY MATRIX PROPERTIES; 3501-5 E WITH 2% MOISTURE

REFERENCE TEMP. - 273.00
TEST TEMP. - 294.00
MOISTURE CONDUCTIVITY - .1000+00
MOISTURE DENSITY - .1000+01
DRY GLASS TRANS. TEMP. - 460.00
PCT. MOISTURE - 2.000
MOISTURE HEAT CAPACITY - .1000+00

ORIGINAL MATRIX PROPERTIES

1	ELASTIC MODULUS	EMS	.4600+06
2	SHEAR MODULUS	GMS	.1643+06
3	POISSON'S RATIO	NUMS	.4000+00
4	THERM. EXP. COEF.	CTEMS	.320C-04
5	DENSITY	RHOMS	.4430-01
6	HEAT CAPACITY	CMSC	.2500+00
7	HEAT CONDUCTIVITY	KMS	.1250+01
8	STRENGTHS	SMST	.6800+04
9		SMSC	.3630+05
10		SMSS	.7000+04
11	MOISTURE COEF	BTAMS	.4000+00
12	DIFFUSIVITY	DIFMS	.2000-03

NEW PROPERTIES: CHANGED BECAUSE
OF TEMPERATURE/MOISTURE EFFECTS

*	NEW EMS	.3068+06
*	NEW GMS	.1096+06
*	NEW NUMS	.4000+00
*	NEW CTEMS	.4797-04
*	NEW RHOMS	.4547-01
*	NEW CMSC	.3748+00
*	NEW KMS	.1874+01
*	NEW SMST	.4536+04
*	NEW SMSC	.2421+05
*	NEW SMSS	.4669+04
*	NEW BTAMS	.4000+00
*	NEW DIFMS	.2000-03

SECONDARY COMPOSITE PROPERTIES; S-GLASS WITH 2% MOISTURE IN MATRIX

BASED ON INTEGRATED THEORY FOR PREDICTING THE HYGROTHERMOMECHANICAL RESPONSE OF ADVANCED COMPOSITE STRUCTURAL COMPONENTS.

FIBER VOLUME RATIO - .550 MATRIX VOLUME RATIO - .440
VOID CONDUCTIVITY - .1000+00 VOID VOLUME RATIO - .010

1	ELASTIC MODULI	ESC1	.6981+07
2		ESC2	.1303+07
3		ESC3	.1303+07
4	SHEAR MODULI	GSC12	.5872+06
5		GSC23	.5872+06
6		GSC13	.5872+06
7	POISSON'S RATIO	NUSC12	.2860+00
8		NUSC23	.1098+00
9		NUSC13	.2860+00
10	THERM. EXP. COEF.	CTESC1	.3840-05
11		CTESC2	.1932-04
12		CTESC3	.1932-04
13	DENSITY	RHOSC	.6951-01
14	HEAT CAPACITY	CSC	.2289+00
15	HEAT CONDUCTIVITY	KSC1	.4950+01
16		KSC2	.3617+01
17		KSC3	.3617+01

18	STRENGTHS	SSC1T	.2027+06
19		SSC1C	.9655+05
20		SSC2T	.4470+04
21		SSC2C	.2386+05
22		SSC12	.4601+04
23	MOIST. DIFFUSIVITY	DSC1	.8800-04
24		DSC2	.5168-04
25		DSC3	.5168-04
26	MOIST. EXP. COEF.	BTASC1	.9209-02
27		BTASC2	.1102+00
28		BTASC3	.1102+00
29	FLEXURAL MODULI	ESC1F	.6981+07
30		ESC2F	.1303+07
31	STRENGTHS	SSC23	.4601+04
32		SSC1F	.1635+06
33		SSC2F	.9411+04
34		SSCSB	.6902+04
35	PLY THICKNESS	TSC	.5000-02
36	INTERPLY THICKNESS	PLSC	.7020-04
37	INTERFIBER SPACING	PLSCS	.7020-04

FLEXURAL STRENGTH

THEORY	LONGITUDINAL	TRANSVERSE
BILINEAR SOLUTION	.1308+06	.7529+04
LINEAR RECTANGULAR SOLUTION	.1650+06	.8802+04
NEUTRAL AXIS SHIFT SOLUTION	.1650+06	.8802+04
PARABOLIC SOLUTION	.1635+06	.9411+04
RECTANGULAR SOLUTION	.1962+06	.1129+05

HYBRID COMPOSITE PROPERTIES; AS/E//S-G/E,80/20 WITH 2% MOISTURE IN MATRIX
BASED ON PREDICTION OF PROPERTIES OF INTRAPLY HYBRID COMPOSITES
(RULE OF MIXTURES).

PRIMARY COMPOSITE VOLUME RATIO - .800

SECONDARY COMPOSITE VOLUME RATIO - .200

1	ELASTIC MODULI	EHC1	.1560+08
2		EHC2	.1003+07
3		EHC3	.1003+07
4	SHEAR MODULI	GHC12	.5319+06
5		GHC23	.4651+06
6		GHC13	.5319+06
7	POISSON'S RATIO	NUHC12	.2860+00
8		NUHC23	.7566-01
9		NUHC13	.2860+00
10	THERM. EXP. COEF.	CTEHC1	.6714-06
11		CTEHC2	.2103-04
12		CTEHC3	.2103-04
13	DENSITY	RHOHC	.5763-01
14	HEAT CAPACITY	CHC	.2418+00
15	HEAT CONDUCTIVITY	KHC1	.2568+03
16		KHC2	.5049+01
17		KHC3	.5049+01
18	STRENGTHS	SHC1T	.2181+06
19		SHC1C	.1178+06
20		SHC2T	.4470+04

```
21                                   SHC2C        .2386+05
22                                   SHC12        .4601+04
23     MOIST. DIFFUSIVITY            DHC1         .8800-04
24                                   DHC2         .5168-04
25                                   DHC3         .5168-04
26     MOIST. EXP. COEF.             BTAHC1       .4738-02
27                                   BTAHC2       .1121+00
28                                   BTAHC3       .1121+00
29     FLEXURAL MODULI               EHC1F        .1560+08
30                                   EHC2F        .1003+07
31     STRENGTHS                     SHC23        .4601+04
32                                   SHC1F        .1912+06
33                                   SHC2F        .9411+04
34                                   SHCSB        .6902+04
35     FIBER VOL. RATIO              VFH          .5500+00
```

```
I**************************************************************I
I                        FLEXURAL STRENGTH                     I
I                        *****************                     I
I**************************************************************I
I THEORY               I     LONGITUDINAL     I    TRANSVERSE  I
I**************************************************************I
I BILINEAR             I       .1530+06       I       .7529+04 I
I SOLUTION             I                      I                I
I**************************************************************I
I LINEAR RECTANGULAR   I       .1882+06       I       .8802+04 I
I SOLUTION             I                      I                I
I**************************************************************I
I NEUTRAL AXIS SHIFT   I       .1882+06       I       .8802+04 I
I SOLUTION             I                      I                I
I**************************************************************I
I PARABOLIC            I       .1912+06       I       .9411+04 I
I SOLUTION             I                      I                I
I**************************************************************I
I RECTANGULAR          I       .2295+06       I       .1129+05 I
I SOLUTION             I                      I                I
I**************************************************************I
```

Using IATEST2

This method is used to check the interactive mode of INHYD. IATEST2 is a dataset that, when called, automatically inputs data as the user would enter it point by point in the interactive mode. It can be used to test this mode quickly. This INHYD.IATEST2 dataset is shown here:

```
0.20E+00
PRIMARY
FIBER
   AS GRAPHITE FIBER
32.E+06,2.E+06,2.E+06,1.E+06,.2,.25
-.56E-06,5.6E-06,.06,1.E+4,3.E-04,.17
580.0,58.0,58.0,400.E+03,400.E+03
TMAT
   EPOXY MATRIX - 3501-5 -  70F - DRY
.46E+06,.1643E+06,.4,32.E-06,.443E-01,.25
1.25,6.8E+03,36.3E+03,7.E+03,0.4,2.0E-04
273.0,460.0,294.0,0.00
55/45 AS/E
.55,.45,0.0
HTM
SECONDARY
FIBER
   S-GLASS FIBER
12.4E+06,12.4E+06,5.17E+06,5.17E+06,.2,.20
2.8E-06,2.8E-06,.09,204.,3.6E-04,.17
7.5,7.5,7.5,.36E+06,.36E+06
TMAT
   EPOXY MATRIX - 3501-5 -  70F - DRY
.46E+06,.1643E+06,.4,32.E-06,.443E-01,.25
1.25,6.8E+03,36.3E+03,7.E+03,0.4,2.0E-04
273.0,460.0,294.0,0.00
55/45 S-G/E
.55,.45,0.0
HTM
80/20   AS/E//S-G/E
RULE OF MIXTURES
```

To start a run, the user must follow this procedure, after logging on a terminal:

```
@ASG. A INHYD
@MAP, I .ABS
  IN INHYD.
  END
@XQT .ABS
```

The computer returns INHYD to be run in the batch or interactive (B/I) mode; the user selected interactive. Instead of entering the secondary composite volume ratio (which is in the dataset), the user enters ADD INHYD.IATEST2, as shown here.

```
           INHYD INTERACTIVE DATA ENTRY

 SECONDARY COMPOSITE VOLUME RATIO
>@add inhyd.iatest2


 WHICH COMPOSITE DATA TO BE ENTERED (P/S)

 PROPERTIES TO BE ENTERED (C/F/M/T)

 INPUT DATA HEADING (1 TO 80 CHARACTERS)

 ENTER THE FIBER PROPERTY VALUES
 EFP1    EFP2    GFP12   GFP23   NUFP12  NUFP23
 CTEFP1  CTEFP2  RHOFP   NFP     DIFP    CFPC
 KFP1    KFP2    KFP3    SFPT    SFPC

 PROPERTIES TO BE ENTERED (C/F/M/T)


INPUT DATA HEADING (1 TO 80 CHARACTERS)

ENTER THE MATRIX PROPERTY VALUES
EMP     GMP     NUMP    CTEMP   RHOMP   CMPC
KMP     SMPT    SMPC    SMPS    BTAMP   DIFMP

ENTER THE THERMAL/MOISTURE PROPERTY VALUES
TO      TGDR    TEMP    MOIST (%)

COMPOSITE HEADING (1 TO 80 CHARACTERS)

ENTER  CONSTITUENT VOLUME RATIOS
FIBER   MATRIX  VOID

METHOD FOR CALCULATING COMPOSITE PROPERTIES (H/M)

WHICH COMPOSITE DATA TO BE ENTERED (P/S)

PROPERTIES TO BE ENTERED (C/F/M/T)

INPUT DATA HEADING (1 TO 80 CHARACTERS)

ENTER THE FIBER PROPERTY VALUES
EFS1    EFS2    GFS12   GFS23   NUFS12  NUFS23
CTEFS1  CTEFS2  RHOFS   NFS     DIFS    CFSC
KFS1    KFS2    KFS3    SFST    SFSC

PROPERTIES TO BE ENTERED (C/F/M/T)

INPUT DATA HEADING (1 TO 80 CHARACTERS)

ENTER THE MATRIX PROPERTY VALUES
EMS     GMS     NUMS    CTEMS   RHOMS   CMSC
KMS     SMST    SMSC    SMSS    BTAMS   DIFMS

ENTER THE THERMAL/MOISTURE PROPERTY VALUES
TO      TGDR    TEMP    MOIST (%)

COMPOSITE HEADING (1 TO 80 CHARACTERS)

ENTER CONSTITUENT  VOLUME RATIOS
```

```
FIBER   MATRIX  VOID

METHOD FOR CALCULATING COMPOSITE PROPERTIES (H/M)

HYBRID HEADING (1 TO 80 CHARACTERS)

METHOD FOR CALCULATING HYBRID PROPERTIES (R/M)
```

The computer then tabulates the data taken from the dataset INHYD.IATEST2. This tabulation is done in exactly the same format as is shown for the example with moisture and temperature effects used earlier and therefore is not listed here. The listing includes the tabulation of the hybrid composite properties and the flexural strengths.

INHYD Batch Mode

From Terminal

The program is started as with the interactive mode according to the system in use. At the Lewis Research Center on the UNIVAC 1110, the following procedure is used:

```
@ASG. A INHYD
@MAP, I .ABS
  IN INHYD.
  END
@XQT .ABS
  B
```

The command selects the batch mode. Next the user adds a previously prepared dataset that contains the needed input data in the form desired. For example,

```
@ADD INHYD.DAT1
```

The format of the input data for running INHYD in a batch mode is shown on the next page for INHYD.DAT1. The "scale" entries were added to orient the input data in the proper columns and are not part of the actual data entry. Each table entry is identified after the input table.

```
>@ed,u inhyd.dat1

CASE UPPER ASSUMED
ED 16R1A-FRI-04/22/83-13:59:43-(23,24)
EDIT
0:>scale

12345678901234567890123456789012345678901234567890123456789012345678901
0:>1

       0.20E+00
1:>p 20

       0.20E+00
PRIMARY
FIBER
   AS GRAPHITE FIBER
        32.E+06          2.E+06          2.E+06          1.E+06             .2
            .25       -.56E-06         5.6E-06           .063          1.E+04
         3.E-04            .17           580.0           58.0            58.0
       400.E+03       400.E+03
TMAT
   EPOXY MATRIX  -  3501-5  -   70F  -  DRY
        .46E+06       .1643E+06             .4         32.E-06        .443E-01
            .25           1.25        14.0E+03        36.3E+03        16.0E+03
            0.4        2.0E-04
          273.0          460.0           394.0            0.00
55/45 AS/E
            .55            .45             0.0
```

```
HTM
SECONDARY
FIBER
   S-GLASS FIBER
20:>scale

123456789012345678901234567890123456789012345678901234567890123456789012
20:>p 20

   S-GLASS FIBER
       12.4E+06       12.4E+06       5.17E+06       5.17E+06            .2
            .20       2.8E-06        2.8E-06             .09          204.
        3.6E-04          .17             7.5             7.5           7.5
        .36E+06        .3E+06
TMAT
   EPOXY MATRIX - 3501-5 -  70F - DRY
        .46E+06     .1643E+06             .4        32.E-06       .443E-01
            .25          1.25       14.0E+03        36.3E+03      16.0E+03
            0.4       2.0E-04
          273.0         460.0          394.0           0.00
55/45 S-G/E
            .55           .45            0.0
HTM
80/20 AS/E//S-G/E
ROM
EOF:35 SCAN:15
0:>scale

123456789012345678901234567890123456789012345678901234567890123456789012
```

The entries in the DAT1 input table (symbols defined in appendix C) are as follows:

```
PRIMARY
FIBER
   AS GRAPHITE FIBER
     EFP1       EFP2       GFP12      GFP23      NUFP12
     NUFP23     CTEFP1     CTEFP2     RHOFP      NFP
     DIFP       CFPC       KFP1       KFP2       KFP3
     SFPT       SFPC
TMAT
   EPOXY MATRIX - 3501-5 - 70F - DRY
     EMP        GMP        NUMP       CTEMP      RHOMP
     CMPC       KMP        SMPT       SMPC       SMPS
     BTAMP      DIFMP
     TO         TGDR       TEMP       %MOISTURE
55/45 AS/E
     FVR        MVR        VVR
HTM
SECONDARY
FIBER
   S-GLASS FIBER
     EFS1       EFS2       GFS12      GFS23      NUFS12
     NUFS23     CTEFS1     CTEFS2     RHOFS      NFS
     DIFS       CFSC       KFS1       KFS2       KFS3
     SFST       SFSC
TMAT
   EPOXY MATRIX - 3501-5 - 70F - DRY
     EMS        GMS        NUMS       CTEMS      RHOMS
     CMSC       KMS        SMST       SMSC       SMSS
     BTAMS      DIFMS
     TO         TGDR       TEMP       %MOISTURE
55/45 S-G/E
     FVR        MVR        VVR
HTM
80/20 AS/E//S-G/E
ROM
```

DAT1 contains the volume fraction of secondary composite as the first data entry; it also has the volumetric proportions of fiber, resin (matrix), and voids as well as all of the necessary fiber and matrix properties. All of these data are arranged in the proper format so that the computer can access the data and use it to calculate the primary and secondary composite properties. The program allows for temperature and moisture effects, so the subroutine HTM (which allows for hygrothermo-mechanical effects) is used to calculate the primary and secondary composite properties. The hybrid composite properties are then calculated by the rule of mixtures. Of course, any other property values (and headings) desired can be substituted for those presently contained in the sample data set to make it applicable to any desired intraply hybrid composite.

DAT2 is to be used if primary composite properties are known but secondary composite properties must be calculated from fiber and matrix properties; otherwise, it is similar to DAT1 (see compiled listing). DAT3 uses fiber and matrix properties to calculate primary composite properties when secondary composite properties are known. DAT4 can be used when primary and secondary composite properties are known; it simply uses the rule of mixtures to determine hybrid composite properties. DAT5 is similar to DAT1 but with moisture present. Several other examples can be obtained by doing @ADD INHYD.DAT6, 7, 8, or 9 instead of @ADD INHYD.DAT1 as was done in the preceding example. Any other desired datasets can be made up by using the same format. Using INHYD.START results in a set of several sequential computer runs in which such things as primary and secondary composite ratios in the hybrid composite are varied or in which different properties for the matrix modulus (for example) are varied to study these effects on the calculated hybrid composite properties. To make INHYD.START run, follow this procedure:

```
@ASG. A INHYD
@MAP, I .ABS
  IN INHYD.
  END
@ADD INHYD.START
```

Initiated by Cards

The cards needed to initiate an INHYD run at Lewis are

```
"RUN, M/TP MSBJS, YOH1965, USERS NAME, 20, 200
"Run card includes the project number, the time, and the number of pages allowed but
 would vary with the requirements of the computer center.
"COL 9000FD
@ASG. A INHYD
@MAP, I .ABS
  IN INHYD.
  END
@XQT .ABS
  B
@ADD INHYD.DAT1
It selects the specific run desired from those on file.
@COL 1100FD
  "FIN
```

Concluding Remarks

This users manual provides step-by-step instructions for using the computer program INHYD (INtraply HYbrid composite Design). The instructions are given for both the user-interactive mode and the batch mode of running INHYD. The various options provided in INHYD are demonstrated with appropriate computer runs. Data input formats, sample computer outputs, and symbol lists are included. The general structure, capabilities, and options of INHYD are described in an appendix.

National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio, August 12, 1983

Appendix A
Elements and Subroutines

INHYD consists of a number of elements and subroutines; they are listed alphabetically and described briefly in this section

ASD	17 properties of AS graphite in format to be used in INHYD
CHANGE 1	Edits FIBMT and COMPP to remove comment symbols (C) from three cards (lines) to activate later commands; then calls INHYD.COM when FIBMT and COMPP are used
CHANGE 2	Edits INHYD.FIBMT and COMPP, adding and removing C's from several lines; then calls INHYD.COM
CHANGE 3	Identical to CHANGE 1
CHANGE 4	Adds and removes C's before several lines of FIBMT and COMPP; then calls INHYD.COM
CHANGE 5	Adds and removes C's before several lines of FIBMT and COMPP; then calls INHYD.COM
COM	Packs and prepares INHYD; compiles FIBMT and COMPP; then initiates INHYD.START
COMPILE	Starting INHYD.COMPILE gives a compiled listing of the entire INHYD program (This depends on a UNIVAC control language program at Lewis and would not work at another computer center.)
COMPP	Generates hybrid composite properties based on micromechanics theory
DAT1	Batch run of INHYD for properties of 80/20 AS/E//3501 at 250° F. Calculations are made by using hygrothermomechanical (HTM) theory because of high-temperature use.
DAT2	Calculates hybrid composite properties for 80/20 AS/E//S-Glass/E composite. The 37 primary composite properties for a 55/45 AS graphite/epoxy resin composite are read in. The secondary composite properties are calculated by FIBMT from the S-Glass fiber and 3501 epoxy matrix properties. Then the intraply hybrid composite properties are calculated by the rule of mixtures.
DAT3	Same as DAT2 except that the secondary composite properties are read in and the primary composite is calculated by FIBMT from AS graphite and 3501 resin properties. The rule of mixtures is used to calculate hybrid composite properties.
DAT4	Calculates hybrid composite properties for 80/20 AS/E//S-Glass/E directly from the 37 primary composite and 37 secondary composite properties that are read in. The rule of mixtures is used.
DAT5	Reads in fiber and matrix properties for both primary and secondary composites. Program degrades matrix properties for the given moisture. Primary and secondary composite properties are calculated by using FIBMT (HTM can be substituted in place of FIBMT). Finally, the 80/20 AS/E//S-Glass/E hybrid composite properties are calculated from the primary and secondary composite properties by using COMPP, which uses the micromechanics theory.
DAT6	Calculates the properties of a uniaxial fibrous composite from its fiber and matrix properties by using FIBMT
DAT7	Calculates the hybrid composite properties for 80/20 HMS/E//S-Glass/E directly from the 37 primary composite and 37 secondary composite properties that are read in. The rule of mixtures is used.

DAT8	Calculates the hybrid composite properties for 80/20 AS/E//S-Glass/E by using micromechanics theory. Input is the fiber and resin properties of the constituents.
DAT9	Calculates the hybrid composite properties for 80/20 AS/E//S-Glass/E. Input is the fiber and resin properties of the constituents. Primary and secondary composite properties are calculated by using micromechanics theory. Hybrid composite properties are then calculated by using the rule of mixtures. No temperatures or moisture effects are involved.
EPOXYD	Contains the 12 properties of an epoxy resin in proper format to be used by INHYD
EPOXYMD	Same as EPOXYD but with a different value for resin modulus
EXE	Contains commands in INHYD and END
EXE2	Identical to EXE
EXP	Contains fiber and matrix properties for a 57/43 S-Glass/3501 composite. No moisture or temperature effects are involved.
FIBMT	Calculates primary or secondary composite properties by using micromechanics theory
FLEXX	Calculates and prints the flexural strength of any composite by using several theories (bilinear, linear rectangular, neutral axis shift, parabolic, and rectangular)
HMSD	Contains the 17 properties of HMS graphite fibers
HTM	Calculates primary or secondary composite properties by using hygrothermomechanical theory
IATEST2	Automatically inputs data as a user would enter it in interactive mode for 80/20 AS/E//S-Glass/E hybrid composite; has temperature effect; moisture effect could be added.
IATEST3	Automatically inputs data as a user would enter it in interactive mode for room temperature, dry, 80/20 AS/E//S-Glass/E hybrid composite
INSTR	Dataset containing instructions and explanations useful to INHYD user
INTER	Interactively queries user for input data required for INHYD in interactive mode and then stores it for later use by main program
KEVD	Contains the 17 fiber properties of Kevlar 49
LIST	To get a listing of INHYD, do @START INHYD.LIST. This is not a compiled listing (see COMPILE). (This depends on a UNIVAC control language program at Lewis and it would not work at another computer center.) This command is used for listing and compiling convenience only.
MAIN	Computes intraply hybrid properties as well as primary and secondary composite properties. Output includes elastic moduli, shear moduli, Poisson's ratios, thermal and moisture coefficients, and strengths. The equations are based on references 2 to 4 (appendix B).
MIXRUL	Predicts hybrid composite properties based on the rule of mixtures. See ref. 1 (appendix B).
PRINT	This command prints the elements in the file INHYD.; also gives listings of the following INHYD subroutines: MAIN, HTM, FIBMT, FLEXX, MIXRUL, and COMPP.
RUN	This command, used in the batch mode, starts a test run that includes INHYD.START and INHYD.START2 (see below); it also includes several datasets identified as CHANGES (1 to 5) (see above). Use care in invoking this command; it results in an output of about 3000 pages.

RUNTEST1	Starts INHYD.RUN from a terminal but gives listing from the computer high-speed printer (does not complete run)
SGD	Has the 17 properties of S-Glass fibers needed for determining the properties of a S-Glass/resin composite
START	Causes several sequential computer runs to be printed out of calculated properties of hybrid composites with different primary and secondary composite ratios and composites with different fiber makeup
START2	Same as INHYD.START but uses a resin with different properties (modulus) than START
TAPE	List of INHYD elements in alphabetical order

APPENDIX B

COMPUTER CODE FOR INTRAPLY HYBRID COMPOSITE DESIGN*

C. C. Chamis and J. H. Sinclair
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

ABSTRACT

A computer program has been developed and is described herein for intraply hybrid composite design (INHYD). The program includes several composite micromechanics theories, intraply hybrid composite theories, and a hygrothermomechanical theory. These theories provide INHYD with considerable flexibility and capability that the user can exercise through several available options. Key features and capabilities of INHYD are illustrated through selected samples.

INTRODUCTION

Intraply hybrid composites generally have two kinds of fibers embedded in the matrix. They have evolved as a structural material as a logical sequel to conventional composites and to interply hybrid composites. Intraply hybrid composites have unique features that can be used to meet diverse and competing design requirements in a more cost-effective way than either advanced or conventional composites. Some of the specific advantages of intraply hybrids over the constituent composites are balanced strength and stiffness, balanced bending and membrane mechanical properties, balanced thermal distortion stability, reduced weight or cost, improved fatigue resistance, reduced notch sensitivity, improved fracture toughness or crack-arresting properties, and improved impact resistance. By using intraply hybrids, the designer can obtain a viable compromise between mechanical properties and cost to meet specified design requirements for aerospace structures.

The mechanical behavior of intraply hybrids has been investigated at the Lewis Research Center theoretically and experimentally (refs. 1 to 3). The theoretical methods and equations described in these references together with those for hygrothermal effects (ref. 4) have been integrated into a computer code for predicting hygral, thermal, and mechanical properties of, and thereby designing, intraply hybrid composites. This code is identified as INHYD for INtraply HYbrid-composite Design. The objective of this paper is to describe INHYD with respect to theory, equations, input, output, and its various options.

The capability and various options of the program are briefly described. Typical input for INHYD includes fiber and resin properties or composite properties, volume ratios of the primary and secondary fibers, glass transition temperature of the resin, moisture, and cure and use temperatures. Typical output includes moisture expansion coefficient, thermal expansion coefficients, moduli and strengths (in plane and flexural). Selected samples of

*This appendix is a reprint of NASA TM-82593.

input and output are included to illustrate the flexibility and capability ofINHYD. Also, the planned extensions and couplings with integrated computer programs are briefly discussed.

INTRAPLY HYBRID GEOMETRY AND DEFINITIONS

The generic geometry of intraply hybrids included in INHYD is shown schematically in figure 1. The features to be noted in this figure are as follows:

(1) The schematic shows an eight-ply, unidirectional intraply hybrid. Each ply consists of primary composite (blank) and secondary composite (cross hatched).

(2) The location of the secondary composite is regular and staggered through the thickness of the intraply hybrid.

(3) The coordinate reference axes are 1, 2, and 3, where 1 is taken parallel to the fiber direction, 2 is taken transverse to the fiber direction, and 3 is taken through the thickness. These coordinate axes will be called the material axes. All properties to be discussed in subsequent sections are defined with numerical subscripts corresponding to the material axes.

It is clear from figure 1 that an intraply hybrid is made by laying tapes (tows) of primary composite and tapes (tows) of secondary composite in a definite manner in order to obtain the desired volume ratios of each. For purposes of identification, the primary composite in the hybrid is the one that constitutes the largest volume ratio. This imposes no limitations on either the capability or flexibility of INHYD. Another way to view an intraply hybrid is the one in which the constituent composites are uniformly dispersed in a typical cross-sectional area.

THEORIES INCLUDED IN INHYD

The theories programmed in INHYD have been reported previously and include (1) rule of mixtures (ref. 1), (2) micromechanics equations for hygrothermal effects (ref. 2), and (3) intraply hybrid composite micromechanics (ref. 4). Also, several equations have been programmed for predicting flexural strength and through-the-thickness shear as will be described later. These theories consist of equations that predict intraply hybrid composite properties based on constituent composite (primary and secondary) properties. The constituent composite properties may in turn be predicted by micromechanics equations using fiber and matrix properties. Essential features of these theories are summarized below. The detailed derivations, equations, and justifications are found in the original references.

The rule-of-mixtures equations have the following form (ref. 1):

$$P_{HC} = V_{PC}P_{PC} + V_{SC}P_{SC} \tag{1}$$

where P denotes property and V volume ratio. The subscript HC denotes hybrid composite; PC, primary composite; and SC, secondary composite. Any property of the intraply hybrid composite can be predicted by using equation (1) when the properties of the primary and secondary composites have been specified. Equation (1), though of simple form, does satisfy the three principles of mechanics: force equilibrium, strain compatibility, and stress-strain relationships. Equation (1) predicts values that are in good agreement with measured data (ref. 1) and with other more sophisticated theories (ref. 2). Equation (1) is programmed as two subroutines in INHYD: one for the primary composite and one for the secondary composite. These subroutines require input of constituent composite properties. The individual properties required are summarized in later sections.

The micromechanics equations from reference 4 are programmed in INHYD for predicting composite properties by using fiber and matrix properties and by accounting for hygrothermal effects. These equations are also programmed in two different subroutines: one for predicting primary composite properties and one for predicting secondary composite properties. Calls to these subroutines require inputs of fiber and matrix properties, fiber volume ratio, void volume ratio, use temperature, and moisture. The individual properties needed are described later.

The intraply hybrid composite micromechanics equations from reference 2 are programmed in INHYD. Three subroutines are used: one each for the primary and the secondary constituent composites and one that combines these two into an intraply hybrid. The first two subroutines require fiber and matrix properties; the third requires the primary and secondary composite properties predicted by the first two.

The properties predicted by all of these theories are those that result from uniform response (due to moisture, temperature, or stress) variation through the thickness of the intraply hybrid. Properties resulting from nonuniform response variation through thickness such as flexural strength and short-beam shear strength are considered in the next section.

FLEXURAL PROPERTIES

The equations programmed for flexural properties in INHYD are for flexural strength along the 1- and 2-directions and the accompanying shear strength in the 1-3 plane (short beam shear) in figure 1. Four different equations are programmed for flexural strengths. The equations have not been reported previously. The equations are readily derivable using the well-known simple beam theory and assumed stress variations through the beam thickness at fracture (fig. 3). The four equations included in INHYD were derived by assuming (1) bilinear stress distribution; (2) parabolic stress distribution; (3) linear rectangular stress variation; and (4) rectangular stress distribution (fig. 3). All these distributions are possible in intraply hybrid composites depending on their constituents. The selections of a specific equation requires user interaction based on measured data correlation. The default option in INHYD is the parabolic stress distribution. All four equations are programmed in two different subroutines: one for the primary composite and one for the secondary composite. The corresponding flexural strengths for the intraply hybrid are calculated in the same subroutine for intraply hybrid micromechanics.

The equation for the through-the-thickness shear strength in the 1-3 plane is derived by assuming parabolic shear stress variation. The integral of this parabolic variation is equated to uniform in-plane shear to obtain the desired equation. This results in the following simple relationship: The through-the-thickness shear (short-beam shear) is equal to 1.5 times the corresponding in-plane shear strength. The short-beam shear strength of the intraply hybrid is calculated in the same subroutine as the flexural strength. The equation for predicting the short-beam shear strength in the 2-3 plane (fig. 1) is similar, but it is not programmed in INHYD. The reason that it is not programmed is that experimental data indicate that specimens tested for this shear fail invariably by transverse flexure.

INHYD COMPUTER PROGRAM STRUCTURE

The logic flow of the INHYD computer program is illustrated schematically in figure 2. The theoretical functions of the program are enclosed with double lines. The input, intermediate output, and final output are enclosed with single lines. Typical final uses of the output are enclosed with dashed lines. The various micromechanics theories and requisite subroutine described previously are included in the first double-line block. Those for predicting the intraply hybrid properties are included in the second double-line block. The user controls INHYD through the main subroutine by selecting combinations of the several available options. The options in INHYD are summarized in table I. It is clear from table I that combinations of options can be specified for theory, hybrid, input property sets, and hygrothermal effects.

The input of INHYD is summarized in table II. A sample user input data set when the intraply hybrid properties will be predicted by using fiber and matrix properties is shown in table III . The first set of Booleans are the options for input read-in formats and for environmental effects. The first line of data is the secondary composite volume ratio. The second set of Booleans specify the composite micromechanics subroutines to be used. The alphanumerics describe the primary composite system. The next (third) set of Booleans define the fiber properties that will be read in. This set of Booleans is followed by the primary composite fiber properties: moduli, Poisson's ratios, thermal expansion coefficients, density, number of fibers per end, fiber diameter, heat capacity, heat conductivities, and tensile and compressive strengths. The alphanumeric card following the fiber properties describes the primary composite matrix and the environmental conditions. The next (fourth) set of Booleans specify the matrix properties to be read in. These matrix properties are moduli, moisture expansion coefficient per percent of moisture, thermal expansion coefficients, heat capacity, thermal conductivity, strengths (tensile, compressive, and shear), moisture diffusivities, glass transition temperatures, reference temperature, moisture content, and volume ratios (fiber, matrix, and void). The data following are the input data needed for the fiber and matrix in the secondary composite. The format for these data is similar to those (one for one correspondence) for the primary composite.

Formatted output (compiled data) of the input data for the primary composite fiber properties is shown in table IV and in table V for the matrix. In these tables the Booleans for the various program options, the fiber and matrix types, the volume ratios, and the constituent properties (with the corresponding program name) are displayed. The reader can readily match corresponding values from the user input data (table III) and the compiled data (tables IV and V).

INHYD program output features are summarized in table VI. A sample output for the predicted primary composite properties (using the input data tables IV and V) is illustrated in table VII. The volume ratio values and 37 properties are listed in this table. The various properties are identified by both name and assigned variable used in the program. Note the flexural properties, lines 29 to 34. Note also the ply thickness (line 35), the interply thickness (line 36), and the interfiber spacing (line 37). The format for the outputs of the secondary composite and for the intraply hybrid are similar to that for the primary (table VII).

INHYD PROGRAM CAPABILITY - ILLUSTRATED EXAMPLES

The INHYD program capability and flexibility is illustrated, in part, with typical examples. The effects of hybridization on selected properties are summarized in table VIII for 70° F, dry environmental conditions. The properties shown in this table were predicted by using the user input data in table III. Corresponding properties for the primary, the secondary, and the intraply hybrid composite are summarized. Corresponding properties for the primary composite are the same as those in table VII.

The thermal degradation, due to high temperature, in the properties of two intraply hybrids (AS/E//S-G/E and (AS/E//KEV/E) is illustrated in table IX. It is instructive to note in this table that the thermal degradation is insignificant in longitudinal properties (except longitudinal compressive strength). However, the thermal degradation is considerable (about 30 percent) for transverse and shear properties and for longitudinal compressive strength.

The hygrothermal degradation in the properties of the AS/E//S-G/E intraply hybrid is illustrated in table X. The hygrothermal environments are 70° F with 1 percent moisture and 250° F with 1 percent moisture. Again, the hygrothermal degradation is insignificant for the longitudinal properties, except for the longitudinal compressive strength. On the other hand the 1 percent moisture degrades the transverse and shear properties and the longitudinal compressive strength about 10 percent for the 70° F case and about 30 percent for the 250° F case.

INHYD EXTENSIONS AND COUPLING

The properties predicted by INHYD described previously constitute only the first part of INHYD. The program can be readily extended to predict other properties of intraply hybrids such as impact resistance and fatigue. In addition it can be made a part of or coupled with integrated programs for special or general structural analysis. The near-future planned extensions and couplings with other programs are summarized in table XI. The theory for impact resistance in reference 5 will be used. The theory for fatigue resistance is presently under development and will be reported in the ASTM 6th Conference on Composite Materials: Testing and Design, May 1981. INHYD will be coupled with an in-house laminate analysis code (MFCA, ref. 6). It will also be coupled with three integrated computer programs under in-house development: CODSTRAN - Composite Durability Structural Analysis (ref. 7); COBSTRAN - Composite Blade Structural Analysis (ref. 8); and CISTRAN - Composite Impact Structural Analysis (ref. 9).

CONCLUSIONS

A computer program called INHYD has been developed to predict the properties of unidirectional intraply hybrid composites and, therefore, to assist in the design of these hybrids. Several composite micromechanics and intraply hybrid theories and a hygrothermal mechanical theory in INHYD provide the program with considerable flexibility that the user exercises through combinations of options. These options control the input data, fiber and matrix, unidirectional composite or combinations, the output, and the theory. Selected samples illustrate key features and capabilities of INHYD. INHYD provides the designer or analyst with a convenient analytical means to investigate several intraply hybrids during the preliminary design phases. INHYD can also be used to guide, and therefore keep to a minimum, required characterization of intraply hybrids.

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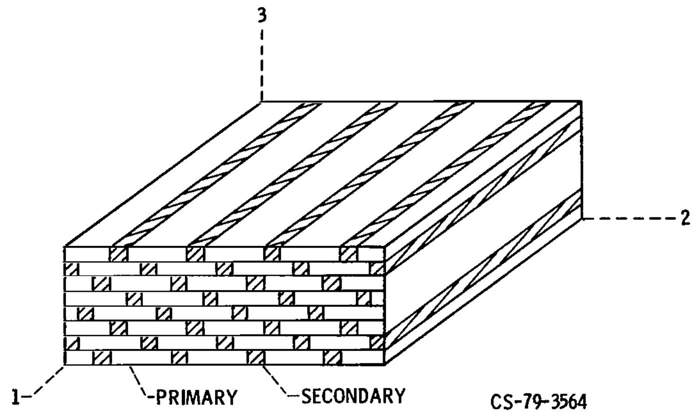

Figure 1. - Schematic of unidirectional intraply hybrid composite.

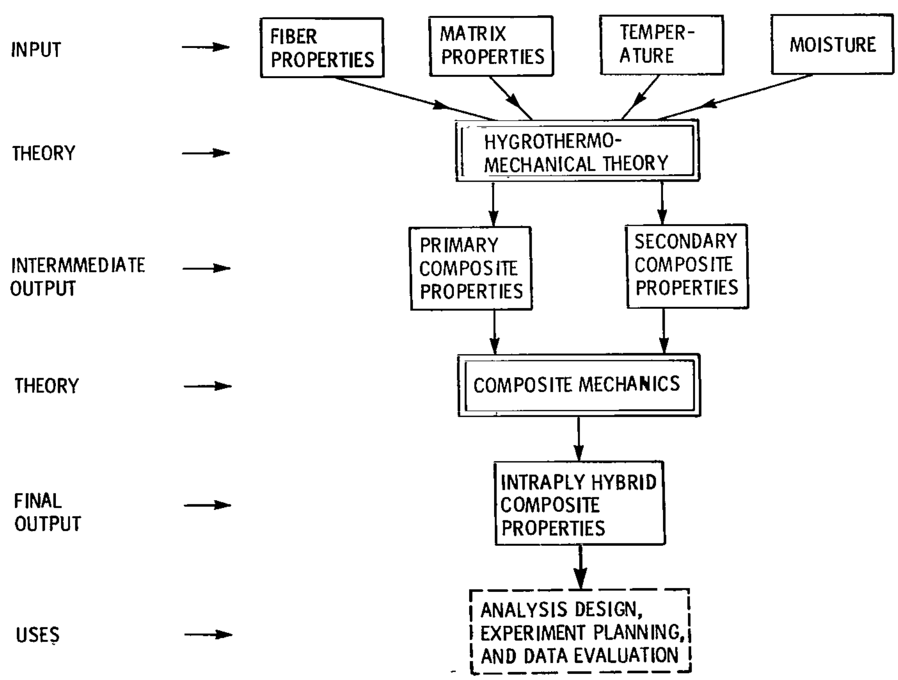

Figure 2. - Flow chart of INHYD computer program.

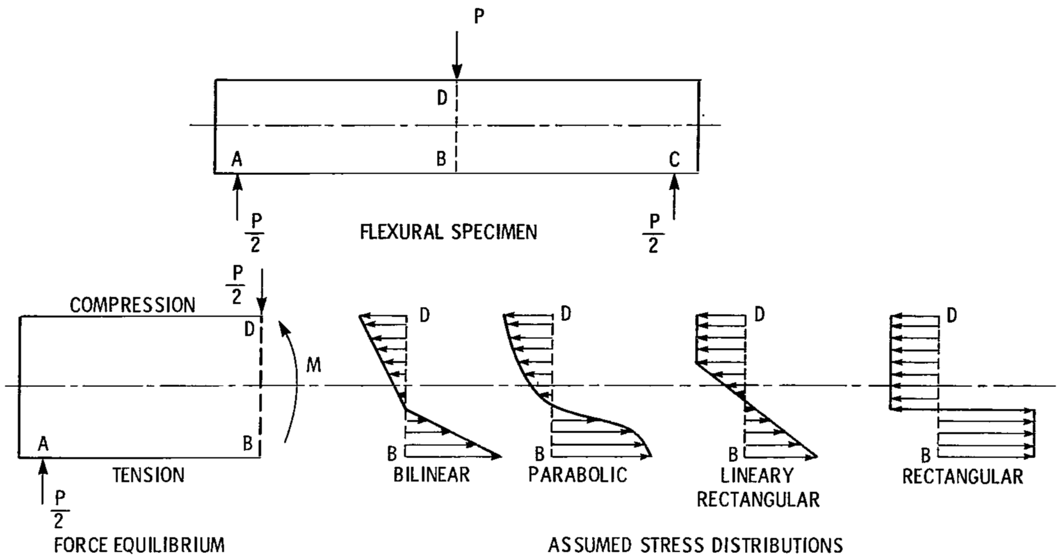

Figure 3. - Geometry, force, and stress distributions for estimating flexural strength.

TABLE I. - PROGRAM OPTIONS

Selects theory to be used
Hybrid or conventional composite
Types of property inputs
Composite properties
Constituent properties
Combinations
Hygrothermal effects

TABLE II. - PROGRAM INPUT

User options
Constituent properties (fiber, matrix) or properties of primary and secondary composites or combinations
Fiber volume ratio, void volume ratio
Primary composite ratio, secondary composite ratio
Temperature, moisture

TABLE III. - USER INPUT DATA

```
F T T T
      0.20E+00
    T
    T
    T
    T
  AS GRAPHITE FIBER
    F
    T
    F
    F
       32.E+06         2.E+06          2.E+06          1.E+06              .2
          .25        -.56E-06         5.6E-06           .063           1.E+04
       3.E-04             .17           580.0            58.0            58.0
     400.E+03        400.E+03
  EPOXY MATRIX - 3501-5 - 250F - DRY
    F
    F
    F
    T
       .46E+06      .1643E+06              .4         32.E-06        .443E-01
          .25            1.25         6.8E+03       36.3E+03          7.E+03
          0.4         2.0E-04
        460.0           394.0             0.0
          .55             .45             0.0
    F
  S-GLASS FIBER
    F
    T
    F
    F
     12.4E+06        12.4E+06        5.17E+06        5.17E+06              .2
          .20         2.8E-06         2.8E-06             .09            204.
      3.6E-04             .17             7.5             7.5             7.5
      .36E+06          .3E+06
  EPOXY MATRIX - 3501-5 - 250F - DRY
```

TABLE IV. - COMPILED DATA - FIBER

VSC= .200+00
MRUL= T PHTMP= T SHTMP= T
PRIM= T

COMP= F FIBER= T MAT= F TMAT= F

PRIMARY FIBER PROPERTIES
AS GRAPHITE FIBER - 250F -

1	ELASTIC MODULI	EFP1	.3200+08
2		EFP2	.2000+07
3	SHEAR MODULI	GFP12	.2000+07
4		GFP23	.1000+07
5	POISSON'S RATIO	NUFP12	.2000+00
6		NUFP23	.2500+00
7	THERM. EXP. COEF.	CTEFP1	.5600-06
8		CTEFP2	5600-05
9	DENSITY	RHOFP	.6300-01
10	NO. OF FIBERS/END	NFP	.1000+05
11	FIBER DIAMETER	DIFP	.3000-03
12	HEAT CAPACITY	CFPC	.1700+00
13	HEAT CONDUCTIVITY	KFP1	.5800+03
14		KFP2	.5800+02
15		KFP3	.5800+02
16	STRENGTHS	SFPT	.4000+06
17		SFPC	.4000+06

TABLE V. - COMPILED DATA - MATRIX

COMP= F FIBER= F MAT= F TMAT= T

PRIMARY MATRIX PROPERTIES
EPOXY MATRIX - 3501-5 - 250F - DRY

TGDR= .4600+03 T= .3940+03 M= .0000

ORIGINAL MATRIX PROPERTIES

1	ELASTIC MODULUS	EMP	.4600+06
2	SHEAR MODULUS	GMP	.1643+06
3	POISSON'S RATIO	NUMP	.4000+00
4	THERM. EXP. COEF.	CTEMP	.3200-04
5	DENSITY	RHOMP	.4430-01
6	HEAT CAPACITY	CMPC	.2500+00
7	HEAT CONDUCTIVITY	KMP	.1250+01
8	STRENGTHS	SMPT	.6800+04
9		SMPC	.3630+05
10		SMPS	.7000+04
11	MOISTURE COEF.	BTAMP	.4000+00
12	DIFFUSIVITY	DIFMP	.2000-03

TABLE VI. - OUTPUT

- PRIMARY AND SECONDARY COMPOSITE PROPERTIES

  3 EACH, ELASTIC MODULI, SHEAR MODULI, POISSON'S RATIOS, THERM. EXP. COEF.

  DENSITY, HEAT CAPACITY

  3 HEAT CONDUCTIVITIES, 5 IN-PLANE STRENGTHS

  3 EACH, MOISTURE DIFFUSIVITIES AND MOISTURE EXPANSION COEFS.

  2 FLEXURAL MODULI

  4 THROUGH-THE-THICKNESS STRENGTHS

  PLY THICKNESS, INTERPLY THICKNESS, INTERFIBER SPACING

- INTRAPLY HYBRID COMPOSITE PROPERTIES

  SAME AS ABOVE EXCEPT FOR LAST LINE PLUS COMPOSITE FIBER VOLUME RATIO

TABLE VII. - TYPICAL COMPUTER OUTPUT OF INTRAPLY HYBRID PROPERTIES

PRIMARY COMPOSITE PROPERTIES

VFP= .5500+00 VMP= .4500+00 VVP= .0000

1	ELASTIC MODULI	EPC1	.1780+08
2		EPC2	.1034+07
3		EPC3	.1034+07
4	SHEAR MODULI	GPC12	.4902+06
5		GPC23	.4148+06
6		GPC13	.4902+06
7	POISSON'S RATIO	NUPC12	.2900+00
8		NUPC23	.2465+00
9		NUPC13	.2900+00
10	THERM. EXP. COEF.	CTEPC1	-.1816-06
11		CTEPC2	.1640-04
12		CTEPC3	.1640-04
13	DENSITY	RHOPC	.5458-01
14	HEAT CAPACITY	CPC	.2048+00
15	HEAT CONDUCTIVITY	KPC1	.3196+03
16		KPC2	.3916+01
17		KPC3	.3916+01
18	STRENGTHS	SPC1T	.2224+06
19		SPC1C	.1712+06
20		SPC2T	.6407+04
21		SPC2C	.3420+05
22		SPC12	.6595+04
23	MOIST. DIFFUSIVITY	DPC1	.9000-04
24		DPC2	.5168-04
25		DPC3	.5168-04
26	MOIST. EXP. COEF.	BTAPC1	.4384-02
27		BTAPC2	.1131+00
28		BTAPC3	.1131+00
29	FLEXURAL MODULI	EPC1F	.1780+08
30		EPC2F	.1034+07
31	STRENGTHS	SPC23	.6595+04
32		SPC1F	.2418+06
33		SPC2F	.1349+05
34		SPCSB	.9893+04
35	PLY THICKNESS	TPC	.5000-02
36	INTERPLY THICKNESS	PLPC	.5850-04
37	INTERFIBER SPACING	PLPCS	.5850-04

TABLE VIII. - EFFECT OF HYBRIDIZATION ON COMPOSITE PROPERTIES

[Dry; temperature, 70° F.]

Property	AS/E primary composite, 80 percent	S-G/E secondary composite, 20 percent	Intraply hybrid composite, 80/20 AS/E//S-G/E
Elastic moduli:			
EHC1	0.1780+08	0.7015+07	0.1564+08
EHC2	0.1034+07	0.1524+07	0.1132+07
Shear moduli:			
GHC12	0.4902+06	0.5517+06	0.5025+06
GHC13	0.4148+06	0.5517+06	0.4422+06
Poisson's ratio, NUHC12	0.2900+00	0.2900+00	0.2900+00
Strengths:			
SHC1T	0.2224+06	0.2037+06	0.2187+06
SHC1C	0.1712+06	0.1448+06	0.1659+06
SHC2T	0.6407+04	0.6407+04	0.6407+04
SHC2C	0.3420+05	0.3420+05	0.3420+05
SHC12	0.6595+04	0.6595+04	0.6595+04
Flexural moduli:			
EHC1F	0.1780+08	0.7015+07	0.1564+08
EHC2F	0.1034+07	0.1524+07	0.1132+07

TABLE IX. - ILLUSTRATION OF THERMAL DEGRADATION IN INTRAPLY HYBRIDS

Intraply hybrid composite property	80/20 AS/E//S-G/E		80/20 AS/E//KEV/E	
	Temperature, °F			
	70	250	70	250
Elastic moduli:				
EHC1	0.1564+08	0.1557+08	0.1670+08	0.1662+08
EHC2	0.1132+07	0.8067+06	0.9365+06	0.6995+06
Shear moduli:				
GHC12	0.5025+06	0.3368+06	0.4504+06	0.3104+06
GHC23	0.4422+06	0.3077+06	0.3715+06	0.2693+06
Poisson's ratio, NUHC12	0.2900+00	0.2900+00	0.3065+00	0.3065+00
Strengths:				
SHC1T	0.2187+06	0.2175+06	0.2227+06	0.2217+06
SHC1C	0.1659+06	0.1432+06	0.1531+06	0.1306+06
SHC2T	0.6407+04	0.4040+04	0.6407+04	0.4040+04
SHC2C	0.3420+05	0.2157+05	0.3420+05	0.2157+05
SHC12	0.6595+04	0.4159+04	0.6595+04	0.4159+04
Flexural moduli:				
EHC1F	0.1564+08	0.1557+08	0.1670+08	0.1662+08
EHC2F	0.1132+07	0.8067+06	0.9365+06	0.6995+06

TABLE X. - ILLUSTRATION OF HYGROTHERMAL DEGRADATION IN

INTRAPLY HYBRID (80/20 AS/E//S-G/E)

Intraply hybrid composite property	Temperature, °F			
	70		250	
	Dry	1.0 Percent moisture	Dry	1.0 Percent moisture
Elastic moduli:				
EHC1	0.1564+08	0.1562+08	0.1557+08	0.1552+08
EHC2	0.1132+07	0.1033+07	0.8067+06	0.5713+06
Shear moduli:				
GHC12	0.5025+06	0.4500+06	0.3368+06	0.2279+06
GHC23	0.4422+06	0.4006+06	0.3077+06	0.2140+06
Poisson's ratio, NUHC12	0.2900+00	0.2900+00	0.2900+00	0.2900+00
Strengths:				
SHC1T	0.2187+06	0.2183+06	0.2175+06	0.2169+06
SHC1C	0.1659+06	0.1584+06	0.1432+06	0.1297+06
SHC2T	0.6407+04	0.5626+04	0.4040+04	0.2631+04
SHC2C	0.3420+05	0.3003+05	0.2157+05	0.1405+05
SHC12	0.6595+04	0.5791+04	0.4159+04	0.2709+04
Flexural moduli:				
EHC1F	0.1564+08	0.1562+08	0.1557+08	0.1552+08
EHC2F	0.1132+07	0.1033+07	0.8067+06	0.5713+06

TABLE XI. - PLANNED EXTENSION

- PROGRAM AND DOCUMENTATION WILL BE MADE AVAILABLE TO THE PUBLIC THROUGH COSMIC
- EXTEND PROGRAM TO DETERMINE IMPACT RESISTANCE, DEFECT PROPAGATION, AND FATIGUE RESISTANCE OF UNIDIRECTIONAL INTRAPLY HYBRIDS
- COUPLE WITH MULTILAYERED FILAMENTARY LAMINATE ANALYSIS (MFCA)
- COUPLE INHYD WITH
  - CODSTRAN - COMPOSITE DURABILITY STRUCTURAL ANALYSIS
  - COBSTRAN - COMPOSITE BLADE STRUCTURAL ANALYSIS
  - CISTRAN - COMPOSITE IMPACT STRUCTURAL ANALYSIS
- CONVERT PROGRAM TO IBM 370/3033

Appendix C
Symbols

This appendix defines the symbols used in the computer program INHYD. Part I displays and defines the property symbols as they appear in INHYD. Part II lists in alphabetical order additional symbols that are used to represent subscripts. In the program the symbols from parts I and II are used together to further define the property.

INHYD. Property Symbols

Primary fiber properties:

EFP1,EFP2	elastic moduli
GFP12,GFP23	shear moduli
NUFP12,NUFP23	Poisson's ratios
CTEFP1,CTEFP2	thermal expansion coefficients
RHOFP	density
NFP	number of fibers per end
DIFP	fiber diameter
CFPC	heat capacity
KFP1,KFP2,KFP3	heat conductivities
SFPT,SFPC	strengths

Primary matrix properties:

EMP	elastic modulus
GMP	shear modulus
NUMP	Poisson's ratio
CTEMP	thermal expansion coefficient
RHOMP	density
CMPC	heat capacity
KMP	heat conductivity
SMPT,SMPC,SMPS	strengths
BTAMP	moisture coefficient
DIFMP	diffusivity

Primary composite properties:

EPC1,EPC2,EPC3	elastic moduli
GPC12,GPC23,GPC13	shear moduli
NUPC12,NUPC23,NUPC13	Poisson's ratios
CTEPC1,CTEPC2,CTEPC3	thermal expansion coefficients
RHOPC	density
CPC	heat capacity
KPC1,KPC2,KPC3	heat conductivities
SPC1T,SPC1C, SPC2T,SPC2C, SPC12	strengths
DPC1,DPC2,DPC3	moisture diffusivities
BTAPC1,BTAPC2,BTAPC3	moisture expansion coefficients

EPC1F,EPC2F	flexural moduli
SPC23,SPC1F SPC2F,SPCSB	strengths
TPC	ply thickness
PLPC	interply thickness
PLPCS	interfiber spacing

Secondary fiber properties:

EFS1,EFS2	elastic moduli
GFS12,GFS23	shear moduli
NUFS12,NUFS23	Poisson's ratios
CTEFS1,CTEFS2	thermal expansion coefficients
RHOFS	density
NFS	number of fibers per end
DIFS	fiber diameter
CFSC	heat capacity
KFS1,KFS2,KFS3	heat conductivities
SFST,SFSC	strengths

Secondary matrix properties:

EMS	elastic modulus
GMS	shear modulus
NUMS	Poisson's ratio
CTEMS	thermal expansion coefficient
RHOMS	density
CMSC	heat capacity
KMS	heat conductivity
SMST,SMSC,SMSS	strengths
BTAMS	moisture coefficient
DIFMS	diffusivity

Secondary composite properties:

ESC1,ESC2,ESC3	elastic moduli
GSC12,GSC23,GSC13	shear moduli
NUSC12,NUSC23,NUSC13	Poisson's ratio
CTESC1,CTESC2,CTESC3	thermal expansion coefficients
RHOSC	density
CSC	heat capacity
KSC1,KSC2,KSC3	heat conductivities
SSC1T,SSC1C, SSC2T,SSC2C, SSC12	strengths
DSC1,DSC2,DSC3	moisture diffusivities
BTASC1,BTASC2,BTASC3	moisture expansion coefficients
ESC1F,ESC2F	flexural moduli
SSC23,SSC1F,	strengths

SSC2F,SSCSB	
TSC	ply thickness
PLSC	interply thickness
PLSCS	interfiber spacing

Hybrid composite properties:

EHC1,EHC2,EHC3	elastic moduli
GHC12,GHC23,GHC13	shear moduli
NUHC12,NUHC23,NUHC13	Poisson's ratio
CTEHC1,CTEHC2,CTEHC3	thermal expansion coefficients
RHOHC	density
CHC	heat capacity
KHC1,KHC2,KHC3	heat conductivities
SHC1T,SHC1C, SHC2T,SHC2C, SHC12	strengths
DHC1,DHC2,DHC3	moisture diffusivities
BTAHC1,BTAHC2,BTAHC3	moisture expansion coefficients
EHC1F,EHC2F	flexural moduli
SHC23,SHC1F, SHC2F,SHCSB	strengths
VFH	fiber volume ratio

Primary matrix properties with moisture:

TO	reference temperature
TEMP	test temperature
KMST	moisture conductivity
RHOMST	moisture density
TGDR	dry glass transition temperature
MOIST%	moisture content, percent
CMST	moisture heat capacity

INHYD. Subscripts

B	bending
C	composite; compression
F	fiber; flexural
H	hybrid
P	primary
S	secondary; shear
1	material axes parallel to fiber direction
2	material axes transverse to fiber direction
3	material axes through thickness

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15. Supplementary Notes

16. Abstract

A computer program (INHYD) has been developed for intraply hybrid composite design. This report is a users manual for INHYD. INHYD embodies several composite micromechanics theories, intraply hybrid composite theories, and an integrated hygrothermomechanical theory. INHYD can be run in both interactive and batch modes. It has considerable flexibility and capability, which the user can exercise through several options. These options are demonstrated through appropriate INHYD runs in the manual.

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